THE COMPLETION OF SINGLE-SPIN ASYMMETRY MEASUREMENTS AT THE PROZA SETUP

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Abstract

Single spin asymmetry in inclusive π^0-production was measured in the polarized target fragmentation region using 50 GeV proton beam. The asymmetry is in agreement with asymmetry measurements in the polarized beam fragmentation region carried out at higher energies. The measurement completed 30-years history of polarized measurements at the PROZA setup.

Introduction

This report is sad in some sense, because it concludes the 30 year's history of PROZA experiment. Nevertheless the new experimental program is planning at IHEP (see S. Nurushev's talk [1]). We present the recent results in inclusive π^0 production as well as the highlights of the previous polarization study at PROZA.

Asymmetry in the unpolarized beam fragmentation region

Single (left-right) spin asymmetry was measured in the reaction $\pi^- + d_\uparrow \to \pi^0 + X$ in the beam fragmentation region. The experimental Setup is presented in Fig. 1. γ-quanta were measured using a lead-glass electromagnetic calorimeter placed at 8 m downstream the target.

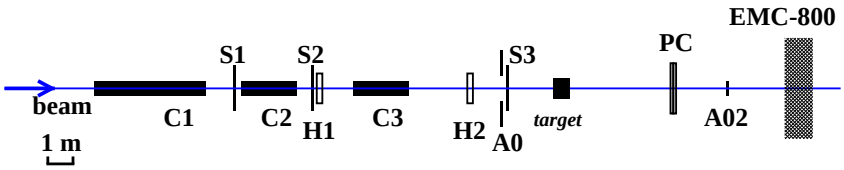


Figure 1. The Experimental Setup PROZA, $S1$-$S3$– trigger scintillator counters, $A0$, $A02$–beam anti-coincidence counters, $H1$-$H2$– beam hodoscopes, PC–Proportional chamber, EMC-800 – Electromagnetic calorimeter

The asymmetry $A_N^{meas}(\phi)$ was calculated for each angle ϕ as the difference of the normalized numbers of pions $n_{\downarrow\uparrow}$ (equivalent to the differential cross-section) for opposite signs of target polarization:

$A_N^{meas}(\phi) = \frac{D}{P_{targ}} \cdot A_N^{raw} = \frac{D}{P_{targ}} \cdot \frac{n_\uparrow - n_\downarrow}{n_\uparrow + n_\downarrow}$

An average polarization value (P_{targ}) of fully deuterized propane-diol target was 35%, dilution factor D=2.5 to 5 decreasing with x_F increases. The procedure to measure carefully the dilution factor is described in detail elsewhere [2]. The asymmetry sign was selected to be consistent with all polarized beam experiments.

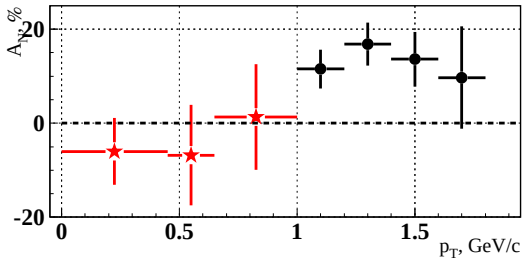


Figure 2. A_N in the reaction $\pi^- + d_\uparrow \to \pi^0 + X$ in the beam fragmentation region. Circles – currents measurements, stars – previous data [2,3]

Final asymmetry A_N was calculated by fitting the measured asymmetry by linear function $A_N^{meas}(\phi) = A_0 + A_N \cdot cos(\phi)$.

The last procedure allowed to eliminate systematic errors caused by beam monitor instability. Asymmetry was measured in the range of $0.6 < x_f < 1.0$ and $1.0 < p_T < 2.0$ GeV/c.

The results are presented in Fig. 2 and in Table 1.

Table 1. A_N in the reaction $\pi^- + d_\uparrow \to \pi^0 + X$

x_F / p_T, GeV/c	1.0-1.2	1.2-1.4	1.4-1.6	1.8-2.0	1.0-2.0
0.6-0.7	-8.6 ± 8.0	2 ± 10.0	-23.0 ± 16.0	2.0 ± 25.0	$\mathbf{-6.5 \pm 5.7}$
0.7-0.8	17.0 ± 8.0	30.0 ± 9.5	24.0 ± 11.0	6.0 ± 16.0	$\mathbf{21.1 \pm 5.1}$
0.8-0.9	7.0 ± 6.6	19.0 ± 8.0	8.9 ± 8.7	13.0 ± 15.0	$\mathbf{11.3 \pm 4.2}$
0.9-1.0	12.4 ± 6.9	8.0 ± 7.0	10.7 ± 10.8		$\mathbf{10.3 \pm 4.5}$
0.7-1.0	11.5 ± 4.1	16.8 ± 4.6	13.6 ± 5.8	9.7 ± 10.9	$\mathbf{13.6 \pm 2.6}$

Surprisingly asymmetry is notable near the edge of phase space:

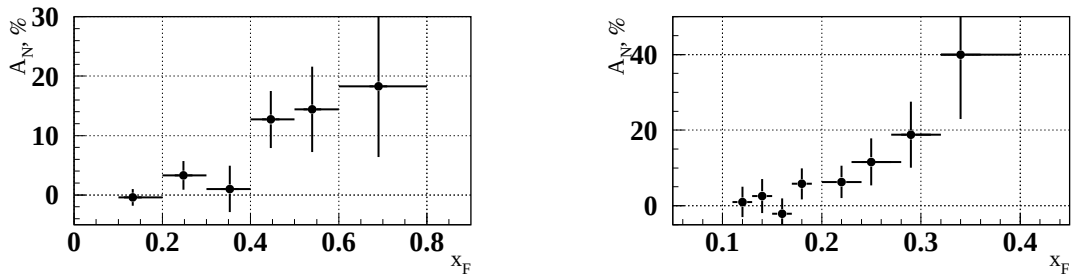
$A_N = (13.6 \pm 2.6(stat) \pm 2.0(syst))\%$ at $p_T > 1$ (GeV/c) and $0.7 < x_F < 1.0$.

Non-zero asymmetry in the unpolarized beam fragmentation region can be explained in some models [4,5]. The asymmetry value in unpolarized π^--beam fragmentation region close to the one found in the same reaction in the polarized target fragmentation region [6], and also to the neutron polarization measured in the reaction $\pi^- + p_\uparrow \to \pi^0 + n$ at the same transferred momentum [7].

Asymmetry was also measured in the reaction $K^- + d_\uparrow \to \pi^0 + X$ at $x_F > 0.7$. $A_N = (-0.4 \pm 6.1)\%$ at $p_T(GeV/c) \leq 1.2$ and $A_N = (11 \pm 6.1)\%$ at $p_T > 1.2$ (GeV/c).

Asymmetry in the polarized target fragmentation region

A_N in the polarized target fragmentation region was measured earlier at PROZA at 40 GeV [6] and 70 GeV [8] (see Fig. 3). We present an asymmetry measurement in the reaction $p + p_\uparrow \to \pi^0 + X$ in the polarized target fragmentation region at 50 GeV. Two sets of data (2005 and 2007) are being used for analysis. The experiment was carried out at the upgraded PROZA-2M setup. The electromagnetic calorimeter was placed at 2.3 m



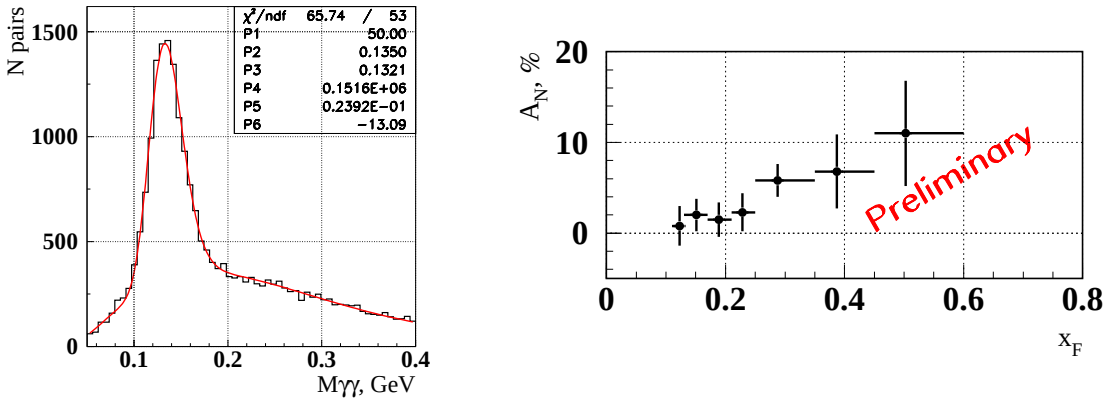
(a) (b)

Figure 3. A_N in the polarized target fragmentation region: **(a)** in the reaction $\pi^- p_\uparrow \to \pi^0 X$ at 40 GeV [6]; **(b)** in the reaction $pp_\uparrow \to \pi^0 X$ at 70 GeV [8]. Results are presented in the polarized proton fragmentation region to be consistent with the polarized beam data.

downstream the target at 30° respect to the beam direction. The geometry was selected to detect neutral pions in the backward hemisphere. A special trigger on transverse momentum p_T allowed to enrich data with negative values of x_F. A special algorithm was developed to reconstruct γ's which hit the detector at large angles (up to 20 degrees) [9]. The π^0 mass spectrum is presented in Fig. 4a.

A single-arm experimental setup was used. A special procedure was used to eliminate systematic errors [6]. The asymmetry was measured at $-0.6 < x_F < -0.2$. The result is presented in Fig. 4b and in Table. 2. x_F and asymmetry values are inverted to be consisted with the existing polarized beam data.

The asymmetry measured at $-0.6 < x_F < -0.25$ $(6.2 \pm 1.5\%)$ is in a very good agreement with the previous PROZA data at 40 GeV $(6.9 \pm 2.8\%)$ [6], the E704 data $(6.3 \pm 0.7\%)$ [10] and with the STAR data [11]. Single-spin asymmetry does not depend on energy in a very wide range. Intermediate energies give us the possibility to measure asymmetry of a variety types of particles with excellent accuracy.



(a) (b)

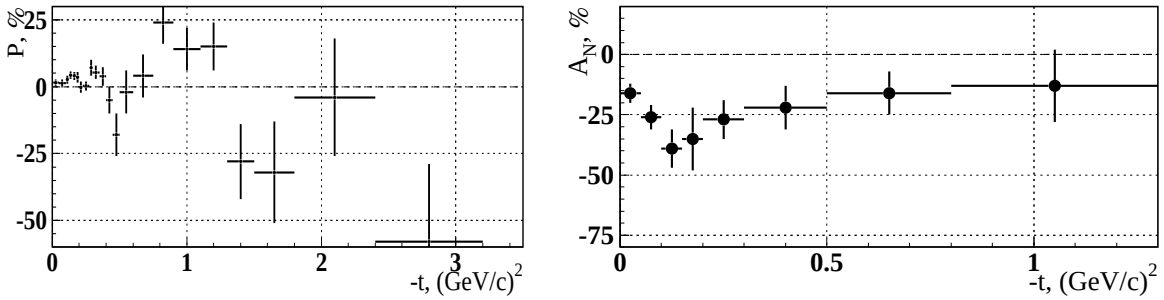
Figure 4. **(a)** $\gamma\gamma$-mass spectrum; **(b)** A_N in the reaction $p + p_\uparrow \to \pi^0 + X$ at 50 GeV.

Table 2. A_N in the reaction $p + p_\uparrow \to \pi^0 + X$ at 50 GeV

x_F	0.11-0.13	0.13-0.17	0.17-0.21	0.21-0.25	0.25-0.35	0.35-0.45	0.45-0.60
A_N,%	0.8 ± 2.2	2.0 ± 1.8	1.5 ± 1.9	2.3 ± 2.1	5.8 ± 1.8	6.8 ± 4.1	11.0 ± 5.8

Highlights of the previous PROZA results

Asymmetry was measured in different exclusive charge-exchange reactions: $\pi^- p_\uparrow \to \pi^0(\eta, \eta\prime(958), w(783), f_2(1270))n$ at 40 GeV [12]- [15]. These results are presented in another talk [1]. Only two out of several ones results are presented in Fig. 5



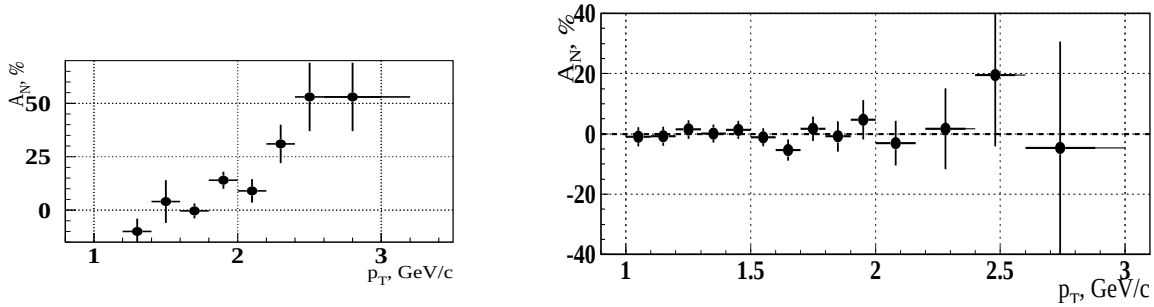
(a) **(b)**

Figure 5. **(a)** Polarization in the reaction $\pi^- + p_\uparrow \to \pi^0 + n$ [12]. **(b)** A_N in the reaction $\pi^- + p_\uparrow \to f_2(1270) + n$ at 70 GeV [13].

Let me remind here the most interesting features of the observed polarization (asymmetry) behavior:

- polarization has a minimum when differential cross-section changes it's slope;
- there are oscillations in polarization behavior;
- there is an indication that asymmetry is bigger for heavier particles.

Lessons from these data will be discussed later. All these asymmetries were measured more than 25 years ago, nevertheless there are no theoretical models describing all the data together.



(a) **(b)**

Figure 6. A_N in the central region in the reactions: **(a)** $\pi^- + N(p,d)_\uparrow \to \pi^0 + X$ at 40 GeV [16]. **(b)** $p + p_\uparrow \to \pi^0 + X$ at 70 GeV [17]. Asymmetry sign is inverted to be consistent with all polarized beam data.

PROZA experiment was one of the first to measure single spin asymmetry in inclusive production. A_N in inclusive π^0-production in the central region is presented in Fig. 6.

Unexpectedly large single-spin asymmetry in π^0-production at π^--beam in the central region [16] pointed out that polarization effects are beam quark flavour dependent, since A_N in $pp_\uparrow$ interactions is zero at the same energy.

Answers and *question* instead of Conclusion

PROZA experiment found many interesting effects both in exclusive and inclusive reactions. Nevertheless even *more questions have to be discussed*.

Let's first summarize what we know and what we *can not explain* in exclusive reactions.

- A significant polarization (asymmetry) was found in the all exclusive reactions [12]-[15]. *Does the asymmetry magnitude increase with meson mass?*
- There is an indication on asymmetry oscillations. *Is it real effect for all particles? Better accuracy is required.*
- Polarization changes it's sign in the dip region on the $\pi^- + p_\uparrow \to \pi^0 + n$ differential cross-section. *Is it valid for other reactions? What is the theoretical explanation of this effect?*
- Simple Regge model can not describe polarization. Modification was required. One of the possible solution is Odderon pole in addition to ρ-pole. *There is no predictions for the most of the reactions* except $\pi^- + p_\uparrow \to \pi^0 + n$ (see [18] for example). *Another interesting prediction is that* $P(\pi^0) + 2P(\eta) = P(\eta\prime)$. *It is very interesting also to measure asymmetry in* $a_0(980)$ *production [19]).*

Similar complicated situation is for inclusive reactions.

- Asymmetry mainly does not depend on energy (see also E704, BNL, RHIC data) *We have very good possibility to measure asymmetry in different channels at intermediate energies with good accuracy at the SPASCHARM experiment.*
- A significant asymmetry was found for $u-$ and $d-$ quark particles. The asymmetry is quark flavor dependent (at least for pion and proton beams). The asymmetry in the η-production is bigger than in the π^0 production (see also STAR data). *What is the asymmetry for* $ss-bar$ *and heavier states* (ϕ *and others)?.*
- Asymmetry increases with p_T at the central region in the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ *Most of the models can not predict non-zero asymmetry in the central region and describe* p_T *behavior.*
- A threshold effect and a scaling was observed. Asymmetry in the non-polarized beam and in the polarized target (beam) regions close to the edge of phase space are equal each other in the reaction $\pi^- + p_\uparrow \to \pi^0 + X$ *It is very important to measure asymmetry in a wide kinematic region in different channels to discriminate between different models.*

We may conclude that we have found a lot of interesting spin effects. Nevertheless we all have desires, possibilities and duties trying to find much more inviting and unpredictable.

Acknowledgement

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